TELEMEDICINE: MEDICINE + TELECOMMUNICATIONS

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The concept of telemedicine along the ending decade maturated enough all over the world to be still treated as an obscure futurible. Numerous practical applications now are merging at the level of institutional bodies or pionnieering individuals having demonstrated their expertise through sufficiently long and unequally successful experiments and follow-ups in teleconsultations at remote places. However, the topic remains blurred mostly because of a lack of synthetic view of what it is defined under the umbrella of "medicine at a distance". Those who approach telemedicine from the technology of telecommunications too often are unaware of who practices routinely what at the level of the patient cares. Conversely, the physicians who enter the field of telemedicine are mostly uncompetent in telecommunication technologies. Moreover, both doctors and technologists have some difficulties to make a realistic approach of the financial benefit which can return on an investment in a telemedicine project.

1 : What does medicine mean?

Medicine is a science of life and an art aiming to diagnose, to treat, to explain and to prevent the diseases which may occur not only in humans but in any kind of living species. Routinely, medicine is more or less limited to the humans whereas veterinary medicine is dedicated to the animals. In the English vocabulary, those who practice (human) medicine are termed physicians or (medical) doctors. There are general practitioners (GP) or specialists. Most of the medical specialities are divided in subspecialties. They are assisted by dedicated human ressources (nurses, technologists, adminstrators...).

2 : How to practice diagnostic medicine?

2.1. The first step is the clinical examination of the patient.

The diagnostic procedure starts with a prominent approach based on a clinical examination performed without sophisticated instruments. Its rules were first described by the Greek Hippocrates 500 years B.C. and were improved during the early last century by Corvisart and Laënnec. The physician uses his/her five senses to look for clinical symptoms. The clinical examination is divided into two entities : the interrogatory and the physical examination.

2.1.1. The interrogatory of the patient still is considered by the Academicians as the key-point of the establishment of the "singular colloquium" between the patient and the physician, whether the latter is a GP or a specialist. Listening to the patient's past and present medical history and discussing the data recollected, the physician fills the first pages of the medical file illustrating the

current disease and the patient's background on which it develops. This oral colloquium may be introduced or completed by letters or manuscripts. The latter may summarized the first contact with the patient when both the patient and the physician cannot communicate through a common language and the eventual help of an interpretor.

2.1.2. The physical examination is made of four investigations encompassing :

* the inspection of the whole patient who is supposed to be naked but, unfortunately more and more often this stage is limited to the inspection of a given and restricted part of the body. The physician is supposed to state carefully on its shape, its color... with an emphasis on the feature of the skin and the mucosae.

* the palpation usually is limited to the symptomatic areas and/or to the abdomen. The physician looks mainly for symptomatic pains and difformities of the organs.
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* the percussion has become a secondary investigation of the human thorax and abdomen using the hands and fingers of the physician.

* the auscultation, using a stethoscope, still is an important investigation of the cardiovascular system and of the lungs.,

2.2. Clinical diagnosis and first algorithm.

At the end of the clinical examination, the symptoms are classified into one or several syndroms, leading to evoke one or several diagnostic hypotheses. Then, a first algorithm is established :

2.2.1. The clinical examination is sufficient to give a credible diagnosis = go to #3.

2.2.2. Complementary investigations are required before a credible diagnosis is issued = go to #2.3.

2.3. Diagnostic complementary investigations.

Complementary investigations are divided into two main groups : biology and imaging.

2.3.1 Biological examinations

* Biochemistry aimed to help the physician by chemical or radio-immunological assays obtained from blood, or urine or humoral samplings to state on abnormalities of catabolites, enzymes... They have been widely automated.

* Biophysics encompasses investigations

acknowledging the physical properties of organs, tissues... e.g. electrocardiography (ECG), audiogram... The less sophisticated one is the measurement of the blood pressure which now belongs to the clinical examination but still requires a device.

* Bacteriological and virological examinations are performed after sampling (blood, urines, cerebrospinal fluid, pus...).

* Pathological examinations, including are performed under optical or electronic microscopy after punctures or surgical biopsy. They should include heamatological examinations accounting blood cells.

2.3.2. Medical imaging

The medical imaging techniques are based upon the use of waves. Numerous technologies aim to image organs and/or regions of the body partly or in total. They have become digitalized and most of the equipments are no more using analogic supports.

2.3.2.1. Radiology and ionizating radiations

Until recently, the concept of radiology was limited to the use of X-rays ("roentgenology"). Some ambiguities exist since a) non ionizing radiations are used by the radiologist; b) artificial radioactivity is at the origin of nuclear medicine, a discipline which has split from radiology in many Western countries. Diagnostic radiology is classified into the group of invasive technique too, because of potential deleterious effects (radiocancers, leukemia, neutropenia...).

* Conventional diagnostic radiology

Conventional radiology is the ancient radiology performed by either radiologists or other doctors. Fluoroscopy alone is no more recommanded or even is prohibited (pulmonary fluoroscopy). The radiologist uses prominently radiography. Most of the radiograms are analogue but, the rate of digital pictures is increasing fastly (computed radiology).
Conventional diagnostic radiology is divided into two groups:

** Plain films based on simple pictures (chest X-ray, plain film of the abdomen, bone film...)

** Special procedures are performed when contrast media must be introduced into the body (intraveinous urography, baryum enema of the colon...). The use of contrast media increases the risk of invasiveness of a procedure.

* Computed tomography

CT means "computed tomography scanner", invented by Hounsfield in the early 70ies. Only the French use other words (scanographie, tomodensitométrie, scanner). The technology has become more

sophisticated since spiral CT can provide ultrafast scanning with pretty 3-dimensional reconstructions. Most of the CT scannings require the use of iodinated contrast media.

* Digital substraction angiography

DSA means "digital substraction angiography". Only the French use the term "angiographie numérique". Modern angiography was introduced by Seldinger in 1952, when he introduced the possibility to perform retrograde catheterism of the femoral artery instead of the direct puncture of the abdominal aorta or the carotid artery to perform selective arteriograms. Angiography can be performed on unsophisticated analogue equipments but at higher risk of invasiveness.

2.3.2.2. Ultrasonography

Medical ultrasonography has boomed dramatically until it was introduced in the 60ies. It is often termed ultrasonic echography. The Americans use the word "Ultrasound" or its acronym US that they divide into "cardiac US" (performed by cardiologists only) and "radiological US" (performed by radiologists or others).

Almost all organs of the body including blood vessels, but excluding bones and normal lungs, can be studied by US, provided that the transducer is applied directly to the dedicated area, since the US waves used for diagnostic US are stopped by air or metals. Thus, most of the transducers are dedicated to limited applications. Except for basic US, an ultrasonograph must be equipped by several transducers or probes.

US is the prototype of the so-called noninvasive medical imaging. However, recently new dedicated contrast media (micro gas bubbles) have been introduced.

Ultrasonography can be used for regular echotomography using gray scale for an anatomic study of the organs through the skin or under endoscopy (transvaginal echography, transrectal echography, trans esophagal echocardiography...). An examination combines echoscopy and pictures. The new apparati are all digital but many older analogue ones are still operational.

Doppler ultrasonography has become a very important development in the diagnostic approach of the cardiovascular system, sometimes replacing the clinical auscultation. It can be performed separately or combined with the conventional US (triplex doppler).

Ultrasonography is the only routine tool available for the imaging of the fetus.

2.3.3.3. Magnetic resonance imaging (MRI)

MRI is the most recent fully digital imaging technique which has

boomed apart from 1981, but at a very expansive cost. Magnetic fields range from 0.1Tesla to 5Tesla. Most of the equipment used in clinical practice are equipped with 0.5 to 1.5Tesla magnets. The examinations are not invasive in themselves but the use of paramagnetic contrast media is often required. MRI has dramatically improved the investigation in neurology. A major field of research and development involves the study of the function of the organs of the body ("functional imaging"). Another development is MR spectroscopy.

Major manufactures supply "multimodality consoles" linking CT, MRI, DSA, US examinations on a single videoscreen.

2.3.3.4. Diagnostic nuclear medicine

The discovery of the artificial radioactivity by the Joliot-Curies led to develop the medical applications of radionucleides. One of these pionneered the "isotopic scintigraphy" which had the monopoly of the imaging of the thyroid gland for three decades. Nuclear medicine forwards imaging and functional data. The must of nuclear medicine is the Positron Electronic Camera (PET scanner), mostly used in the neurosciences, at a very high cost.

2.3.3.5. Miscellaneous

Some diagnostic technologies have become more or less definitely obsolete, e.g. thermography using infra-red waves. Some of them are merging such as

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2.3.3. Diagnostic interventional procedures

The concept of diagnostic interventional procedures has been leaded by the development of superselective angiographic procedures. It is now a patchwork of all investigations based on biopsies and/or catheterism guided under any kind of imaging technique (US, CT, DSA, even MRI...).
percutaneous or endovascular or endoscopic punctures and/or s and/or samplings guidance They are less invasive and more cost-effective than the previous mostly surgical ones.

2.4. Second algorithm : disease or healthy condition?

At the end of the diagnostic stage, the physician concludes on a formal diagnosis of a disease or of a safe condition. Between certainly healthy and ill humans, there are intermediate individuals whose conditions are pending, indicating dedicated follow-ups.

3. Therapeutic stage

The diagnosis of a disease usually leads to prescribe a treatment which can be medical, surgical or both. According to the severity of the disease, the treatment is acceptable at home or requires an hospitalization. The decision may have to be taken in emergency or

be delayed.

3.1. Medical treatments

The large majority of the medical treatments are based upon drugs which are easily

which are available on place. Their effects are more or less easily predictable.

3.2. Surgical treatments

Surgical treatments are almost seldom practicable at home. The patient has to be hospitalized and the surgeon usually has to be assisted by an anaesthesiologist.

3.4. Curative radiology

Now, the concept of curative radiology, using radiotherapy or radionuclides, has been replaced by that of "radiation oncology" since almost all indications are from malignant diseases.

3.5. Therapeutic interventional procedures

Interventional radiology is usually diagnostic first and sometimes can be followed by therapeutic procedures. Transluminal angioplasties are revolutionarizing cardiology and angiology. Tumors and bleedings can be treated by transluminal embolization, US-guided alcoolization, local injection of drugs...

3.6. Miscellaneous

The physician may choose selectively other kinds of therapeutics, ranging from psychanalysis to electrotherapy.

4. The third stage is prognostic

The prognosis of a disease relies on several categories of criteria : severity of the diagnosis, reactivity to the therapeutics, healthy background or associated disease, risk of chronicity and/or recurrence.
The patient may recover totally or develop organic and/or functional sequelae.

5. The fourth stage is Billing

Someone has to pay the medical service. According to the social security system of a given patient, the patient can be charged and reimbursed, can be treated free of charge. The physician can be prepayed or salaried by an institution. The hospital can be a charity institution or a profitable clinic...

6. The last and sometimes the least algorithm: Lawsuit?

Forensic medicine is booming in the most capitalistic countries, since the patient has become a consumer of risky medical services. The medicolegal implications of the modern medicine is raising a high level of complexity with the easier migrations of individuals having different moral, ethical, religious, socio-economical, political specificities. Malpractice is common since the medical advances go faster than the capacity of the physicians to control their knowledge and to update it. The lucrativity of many medical practices is decreasing whereas the cost of the new technologies is increasing.

The current major trends are giving the WASP right a leading influence. More and more countries are adopting procedures of informed consent before the acceptation of a risky diagnostic or therapeutic procedure. Fetal imaging has become the most upsetting medicolegal concern of the medical practice.

In the Western world, the governements are introducing more or less actively new rules and regulations of the medical practice. Doctors and wards have to be accredited . Physicians and medical practices must be evaluated and sometimes periodically re-certified. Continuous Medical Education programs must be followed seriously. There is no doubt that the merging countries will follow such a progress by a not too far future.

7. In fine, the medical ethics is topped by the confidentiality of the "singular colloquium".

"Les paroles s'envolent, seuls les écrits restent".

The risk of impairment of the confidentiality is minimal when the colloquium remains singular inside the personal office of a physician chosen by the patient, without any written record. Unfortunately for the conservative, the fashion is going definitely and unreversebly toward the mandatory written file and, within a rather close future, its computerization. What it is written is the only final argument usable by the experts and lawyers having to state and to judge on the bona fide of the physician and the patient face to a lawsuit for malpractice.

The jungle of computed piracy is a potential room for insurance companies as well as directors of human resources. To keep a medical file out of the undiscrete look of curious gossips as well as of dark detectives opens the way to a new criminality hampering the harmonious devlopement of the computed medicine associated with the telecommunication multimedia facilities.

TELEMEDICINE = MEDICINE AT A DISTANCE

Specialists of telemedicine know that all technical problems dealing with the implementation of telecommunication media have been already solved by the military services linked with the atomic deterrents and the tools for star wars. If there are so many negative reacting strengths against the high pressure put by the lobbies of telecoms and computer industries to develop telemedicine, the exhibited reasons are political, economical and psychological. The hidden reason is the misfit between the three major actors : the physician offering a medical service to satisfy an anxious patient to be secured by a cost-effective consultation. To develop a project on telemedicine requires a precise positioning of the demander face to the enormous number of dangers, constraints and frustrations but also rewards which compose the science and art of the medical practice.

1. The clinical tele-consultation is show business.

There are no technical difficulties to adapt the audio-visual techniques to the clinical examination of a patient by a physician speaking the same language.

The interrogatory is technically easy by telephone and is reliable when a camera enables a visioconferencing in real-time. Telecopy, electronic mailing may be substitutes working in real-time whereas conventional postage, even fast delivery mail, are not usable in case of first emergency or in remote places.

The data from the physical examination cannot be nothing but minimal at a distance. Good visioconferencing is mandatory for the inspection. Auscultation is possible if the acoustics broadcasting is excellent. Percussion and palpation are uneffective, unless a reliable referring physician is aside the patient.

To conclude on this basic topic of the teleconsultation projects, both the patient and the physician or their substitutes must be able to use telecommunication systems to exchange informations mandatory to provide a cost-effective and fast diagnosis at a distance. This is not taught in the universities nor schools of medicine worldwide. Such dialogues are not as easy to manage as one can imagin when usable informations must be obtained in real-time.

2. The teletransmission of complementary investigations is fully dependent from the rate of digital formulation of the collectable data.

To conceive the implementation of biochemistry in Intranet and/or Extranet systems is easy. The results of the biochemical assays are usually obtained directly in a binary language when the wards are located in developed countries and in the major cities of the developing world. Otherwise they are almost always unavailable from remote places at least in emergency. The physician is happy when simple assays can be performed locally, managed handly and broadcasted orally or by telecopy, but with an insecure rate of reliability.

Teleradiology was pionnieered by the conceivor of PACS (picture and archiving communication systems) or IMACS (image management and archiving communication systems). Medical imaging is easier to broadcast when it is digital at the origin and is plugged directly on a telecommunication network. If it is analogue, the images should be converted by a digitalizer. The other methods are unsafe and last resort. Tele-echography is the most difficult drill, since it is not possible to control the operator-dependence of the technique at a distance. In general, medical imaging requires a huge number of octets to be informative. Only the pathologists broadcasting slowly in color are fully successful. Teleendoscopy is spectacularly successful when it is performed by skilled operators using T1 bandwith.

3. Medical drugs, when available at a distance, can be prescribed by telephone or telecopy. Telesurgery is a new world for surgeons and interventionists.

4. The prognosis of the disease evaluated by telecoms relies on the reliability of the interlocutors and of the informations broadcasted.

5. Nobody knows exactly how to charge a telemedical service. At the moment, in Europ, most of the telemedical experiments are free of charge at the level of the patients since they are practice by non-profit institutions. Telemedical business is starting in the United States, mostly in HMOs (Health Managed Cares).

6. Medicolegal concerns and issues of telemedicine are not solved yet. Lawyers, medical experts, insurance companies, politicians are working worldwide. The results are not conclusive yet since the medical systems are heterogeneous, even in the USA. The systems work in remote places, like in Canada, the Polar Circle, the insular countries and so on, when no better medical substitute can be offered instead. A similar condition is observed in the navies. One of the majorproblems evoked by American specialists is the lack of guarantee about the identity and the competence of the referring physician requested to give a diagnosis and a treatment at a distance.

7. Confidentiality is the second hampering factor. The Intelligence services and the military know how to protect or to enforce a secret defense. The problem is not solved if one wish a secure protection of the medical secret. In France, coding below 40 bits is legally free but a good specialist can enter the system. Over, a permission must be requested at the level of the government.

WHAT'S ABOUT THE TELECOMS AND THE MULTIMEDIA?

1. The telecom and multimedia industries are not in charge of the medical schools. The quality of the medical services a patient, a population, a government want to either. They cannot reinvent the science and the art of medicine. Their role is to offer an

adaptation of their products to the physicians for a better medicine.

2. To-day, the politician and the economist are upset by the expanding cost of medicine in general. They are not convinced at all that telemedicine can help them to control such expenditures. They are reluctant toward the ongoing pressure put by the industry, some money-makers and ultra-motivated physicians. But, this is the end of a period of skepticism.

3. The technology of telecommunication exists and the information superhighways promote the expansion of telemedicine. The best target looks the remote places and several kinds of cares given to handicapped people, geriatric patients, desertified places. They aim to decrease the reasons to travel from home to hospitals or far medical offices for trivial disease or benign symptoms.

4. Even though telecommunication facilities have become more efficient,teleconsultations rely mostly on the quality and the quantity of the visioconferencing supplies. Personal apparati are commercially available but their costs are still high. Their diffusion remains confidential. More sophisticated videoconferencing studios are supplied as well but they cannot act medically out of rich or governmental institutions.

5. Bandwith is very important since the standard telecommunication networks are being saturated. To telebroadcast in emergency a short CT scanning through a conventional telephone line to the lap-top of a radiologist suppering in a restaurant after a theater performance is routinely practiced in the USA. Using a 8-15kbps telephone line makes the procedure duration over 20 minutes. ISDN lines which are multiple of 64kbps accelerate the broadcasting of fixed images but the number of lines must be at least 4 for a good transmission of teleechography; the cost of such a visioconference is affordable indeed for those who are not looking for lucrative return in investment. Optic fiber and T1 lines provide more than 1Mbps and should be the gold standard but this remains too expansive for regular teleconsultations. When ATM cells will be available, bandwiths would raised up to 350Mbps.

6. All governements are investing in huge telecommunication systems for their nationals. Continental and world institutions are developing fabulous projects offering multimedia multiple services including telemedicine at home. They encompass two kinds of components:: networks and stations. Networks can be made of ISDN lines but many countries are investing in optic fiber cabled networks with powerful bandwiths.

6. ??? work The digital information is broadcasted through the cable and/or telecommunication satellites. The first projects were conceived with geostationary satellites (Marisat, Inmarsat). Now, a tight competition is expected featuring projects based on multiple little and big low-earth-orbit satellites (Iridium, Globalstar, Orbcomm, Skybridge, Teledesic, ICO...).

Connections with home would be made by cabled TV sets, through the web or personal dishes. In such a perspective, telemedicine would become a pay-off service among others.

7. Whatever the delay of availability of those platforms, many problems remain unsolved yet. The consumers are not demanding urgently telemedical services yet, save those who are living in remote places and have the private or public possibility to afford the payment. When they have the multimedia workstation, the cellular phone-fax, the access to Internet, the voice typing machine, the automatic language translator... the patients and their physicians will have to learn how to use them. Then, they will have to understand how limited the capacity to forward useful informations are when both of them are located at a distance and are in a rush to obtain the best service.

8. Educational programs have to be conceived and promoted in order to prevent problems dealing with malpractice, disrespect of confidentiality, lawsuit, swindle... When they exist, one would expect enough doctors, nurses, technologists... will be numerous enough, skilled and good-willing. Neutral observers may wish the best clue for the future of the compatibility of the computer languages used worldwide. One could bet that JAVA will be the winner. The medical imagers are working on an international standard for their workstations (DICOM 3.0).

9. Investors can be institutional, money-makers, philanthropes... Telemedicine is going to be one of the weapons of national cultural politics. Several scenarii can be featured to imagin the return on investments those people can expect. The role of medical academics is mainly to work on an humanistic approach of that tremendous breakthrough for the next millenium.

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